

Fabrication and Testing of High-Stroke Adaptive Optics Actuator

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The purpose of this project was to build and test a high stroke actuator for use in space telescopes. The unique scissors jack design converts small horizontal displacements into large vertical displacements. Our goal was to reduce this approach to practice.

The specific technology to be incorporated is a MEMS-based actuator for deformable mirrors (DMs) that can be used to correct for aberrations in lightweight space telescopes. These telescopes are under increasingly active investigation to substantially lower costs.

A serious concern with lightweight mirror technologies is how to control their optical quality during both fabrication and deployment, and how to maintain the surface quality on orbit with changing gravitational, centrifugal, and thermal loads. A potential method for correcting aberrations in lightweight space telescope optics is to use a DM to cancel the primary mirror aberrations. As on-orbit changes in the primary mirror occur, the shape of the DM can be readjusted to maintain the correction.

Conventional DMs have many drawbacks — they are expensive, heavy, use significant power, have limited stroke, have limitations on the number of actuators, and do not work in cryogenic environments. MEMS-based adaptive optics (AO) has the potential to address all of these issues.

The goal of achieving a high stroke actuator with 50 μm of vertical displacement was to be accomplished by designing beams that buckle out of the plane of the wafer when they are actuated parallel to the plane of the wafer. To do this, a basic design was worked out that was compatible with a conventional fabrication process.

The design included beams with crenellations engineered to force the beam to buckle in the right direction, electrostatic comb actuators, and stabilizing springs. Two different types of actuator were designed, a two-beam actuator and an eight-beam scissors jack-type actuator.

A computer model was created to describe the predicted performance of the devices. That computer model was then used to find optimal designs. The constraints on the optimal design were the specifications

of the fabrication process on film thicknesses and minimum feature sizes and spacings. The optimal criterion was to make the displacement vs. voltage curve have as large a stable region as possible while reaching 50 μm at 100 V.

The optimal designs and a number of other variations were laid out and submitted to the foundry service. A post-processing method was developed to use a SU-8 photo-curable epoxy block as an insulating mechanical connector between the two high-potential sides of the actuator. Two different release processes were investigated to allow the fragile polysilicon parts to be released from the silicon dioxide in which they were fabricated without permanently sticking together. An existing critical point dryer was re-certified, and a process was implemented to coat the chips with a hydrophobic self-assembled monolayer, akin to coating the pieces with a monolayer of Teflon.

Our test results are as follows.

Probe actuation

The devices were pushed horizontally by mechanical probes and reliably translated the horizontal motion to a vertical motion. This showed that many aspects of the design do indeed work properly; the beams buckle in the correct direction, not downward and not sideways; and the SU-8 epoxy insulating connector works.

Electrostatic actuation

We were not able to actuate devices as predicted electrostatically. One actuator did move vertically under electrostatic actuation, but not with the expected mechanism.

Thermal actuation

We were able to actuate a thermal actuator (Figs. 1 and 2). Simplified versions of the actuators were fabricated without electrostatic elements. Current was run through the beams of these devices to heat them. The expansion of the beams moved the actuators. Buckling was observed at 8 mW, and displacements of as high as 9 μm were observed at 35 mW.

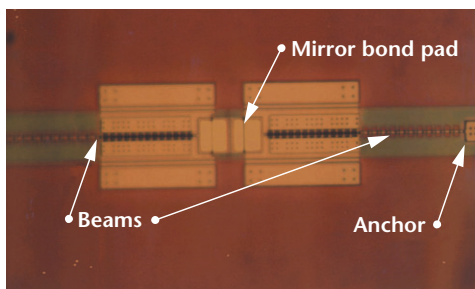


Figure 1. Photograph of thermal actuator.

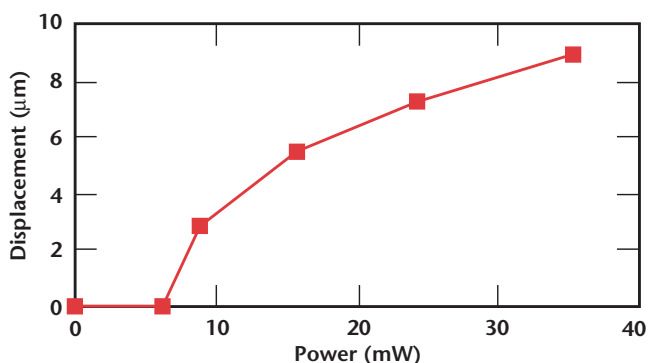


Figure 2. Plot of thermal actuator displacement data.